

Differences in Spatial Tuning for Attended and Remembered Locations in Prefrontal Cortex

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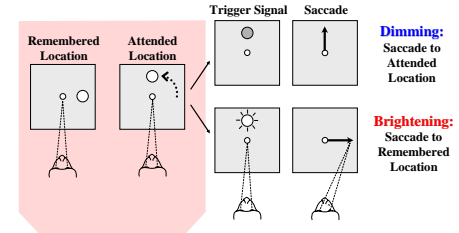
Introduction

- We assessed the role of dorsolateral prefrontal cortex (PFD) in spatial working memory and attention by recording from individual neurons in monkeys that were simultaneously remembering one location and attending to another location.
- Neuronal activity was a function of which location was remembered, which location was attended, or both.
- For each neuron, we computed both its preferred attended location and its preferred remembered location.

Methods

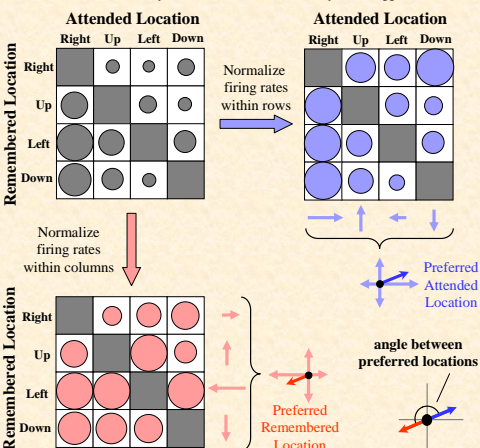
Behavioral Task

- A light spot appeared either up, down, left, or right from a central fixation point.
- The spot then revolved around the fixation point to another location.
- This new location had to be attended to detect a brief change in the spot's luminance.
- Dimming instructed a saccade to the spot's current, attended location.
- Brightening instructed a saccade to the spot's initial, remembered location.



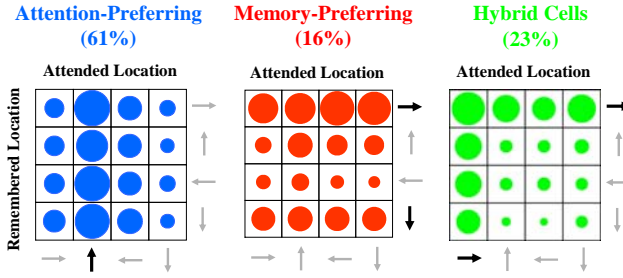
- Analysis**
- The combinations of remembered and attended locations were represented in a 4-by-4 matrix. Gray squares show excluded, control trials in which the spot did not move.
 - Circles (below) of various sizes depict firing rates during the 800 ms preceding the trigger signal for each trial type.
 - Firing rate varied significantly ($p < 0.01$) across columns for **attention-prefering cells**, across rows for **memory-prefering cells**, and across both for **hybrid cells**.

- Preferred locations were calculated by vector averaging of normalized firing rates. Locations were computed as vectors with their tails at the fixation point. We analyzed only "well-tuned" cells, i.e., cells with preferred location vectors longer than 0.1 (where 1.0 indicates maximal activity for one location and no activity for the opposite location).

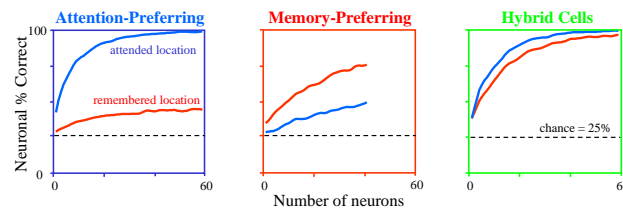


Results

PFD neurons with significant spatial tuning (N=303) were classified into three categories:



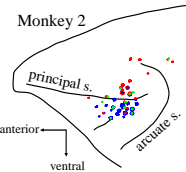
All classes of tuned cells encoded both locations to some extent.



Neuron-dropping curves computed separately for the three cell types. Plots show the percentage of single trials for which the **attended** (blue curves) and **remembered** locations (red curves) were correctly classified as a function of the neuronal ensemble size.

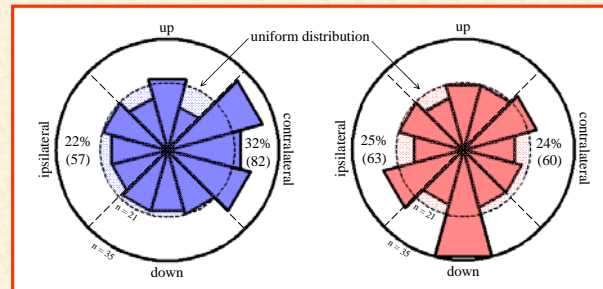
Neurons with significant tuning for the remembered location comprised 70% of tuned neurons dorsal to the principal sulcus but only 20% of those ventral to the principal sulcus.

These two regions differed significantly in their distribution of the three cell types ($p < 0.001$, χ^2 test, $df = 3$).



Distribution of Preferred Locations

(N=254 well-tuned neurons)

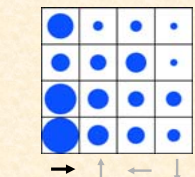
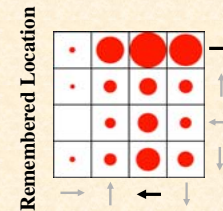
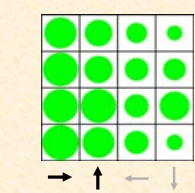


The **preferred attended location** had a significant contralateral bias but... the **preferred remembered location** did not ($p < 0.05$, χ^2 test, $df = 1$).

Preferred Attended vs. Preferred Remembered Location

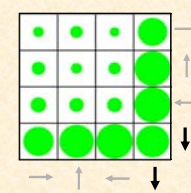
Diametric Tuning

Attended Location



Congruent Tuning

Attended Location



- The number of congruent, diametric, and intermediately tuned cells differed significantly (χ^2 test, $df=2$) from expected levels for all tuned neurons ($p < 0.005$), hybrid cells ($p < 0.001$), and memory-prefering cells ($p < 0.05$).

- In each case, there were significantly more diametrically tuned neurons than expected. Memory-prefering cells had significantly fewer congruently tuned neurons than expected.

- The inner shaded semicircle in each plot shows the expected distribution for independent tuning.

Conclusions

- The activity of many PFD neurons reflected both the remembered and attended locations. These neurons appear to be multitasking, i.e., simultaneously contributing to mnemonic and attentional processing.
- For cells with different preferred attended and remembered locations, spatial processing was a function of the cognitive operation in question.
- The preferred locations of most cells were either similar (congruent tuning) or nearly opposite (diametric tuning). Cells with congruent tuning signal a specific location but not whether this location is being remembered or attended. Cells with diametric tuning signal either memory for one location or attention towards the opposite location.
- Both the attended and remembered locations cannot be ascertained from just hybrid neurons with congruent or diametric tuning. However, these cell types can specify both locations in conjunction with each other or in conjunction with either attention- or memory-prefering neurons.

Reference

M. A. Lebedev, A. Messinger, J. D. Kralik, and S. P. Wise (2004). Representation of Attended Versus Remembered Locations in Prefrontal Cortex. *PLoS Biology*. 2 (11): in press, [doi: 10.1371/journal.pbio.0020365].

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